Analysis of hydrological components of the Wüstebach catchment by means of stable isotope measurements

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Motivation

Over the past decades, interpretation of changes in stable isotope signatures of catchment waters have been used to assess hydrological flow paths under different flow conditions and estimating mean catchment residence times. However, despite of the many studies the timing, flow path, and source behavior of catchments are still not well understood.

In this study we investigate the hydrological components of the Erkensruhr catchment (Fig. 5), Germany, and the Wüstebach sub-catchment (27 ha) using stable isotopes of water ($^{2}H/^{1}H$ and $^{18}O/^{16}O$) as tracers.

Precipitation (A)

Precipitation-$\delta^{18}O$ as input to the catchment shows seasonal effects, with throughfall having generally higher values due to evaporation on leaves. A declining trend changes to an ascending trend at the beginning of 2011 (Fig. 1).

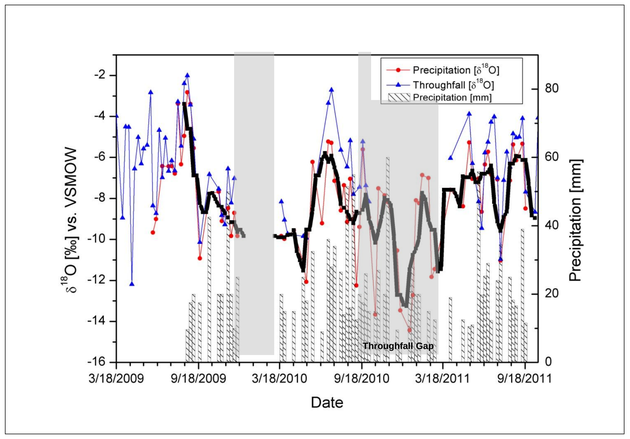

Fig. 1: Seasonal effect on precipitation (red circles). The 5-month, rainfall-amount weighted moving average (black line) highlights a descending and ascending trend. Throughfall (blue triangles) shows generally higher $\delta^{18}O$ values than precipitation (evaporation). Rainfall amount is shown for single events by lined columns. Grey shaded areas are sampling gaps.

Stream Water (B)

All stream-$\delta^{18}O$ values show the same declining and ascending trend as precipitation, indicating a fast runoff response (Fig. 2).

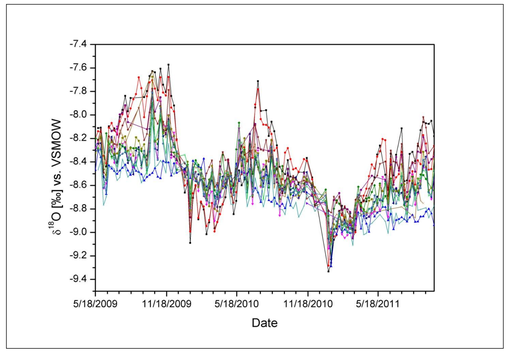

Fig. 2: Stream water samples of all 16 sampling points. A descending trend can be seen until beginning of 2011, where an ascending trend starts. All samples have been taken in weekly intervals.

$\delta^{18}O$ Dampening (C)

The seasonal effect on stream water-$\delta^{18}O$ values near the Wüstebach spring is dampened by the quasi-constant input of groundwater at point Wu03 (3 on the map) (Fig. 3).

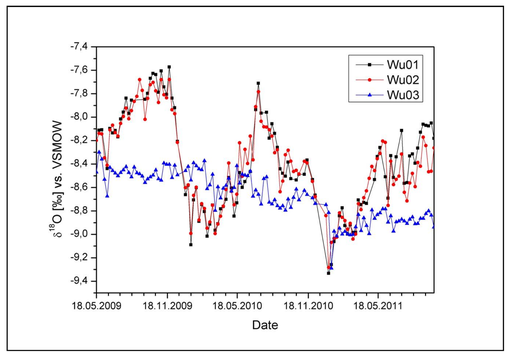

Fig. 3: Seasonal effect on $\delta^{18}O$ values of Wu01 and Wu02 (main stream), indicating a shallow water source and quasi-constant Wu03 (tributary) $\delta^{18}O$ values, indicating a deeper groundwater source.

Project Site

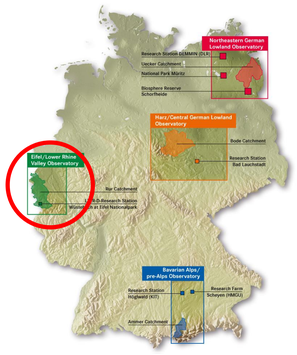

Fig. 4: TERENO (Terrestrial Environmental Observatories) test sites, with Eifel/Lower Rhine Valley highlighted.

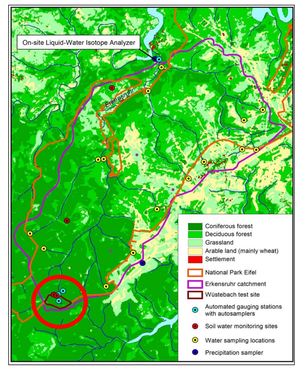

Fig. 5: Erkensruhr catchment (45 km²), with Wüstebach sub-catchment highlighted.

Wüstebach-Catchment

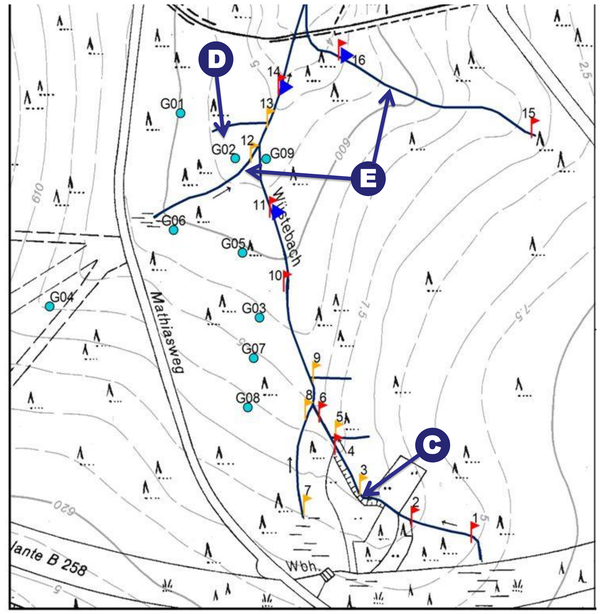

Fig. 6: Wüstebach catchment measurement network with stream (1-16, yellow and red flags) and groundwater (G01-G09, turquoise dots) sampling points, as well as three gauging stations (blue, sideways triangles).

Groundwater (D)

All groundwater-$\delta^{18}O$ values have the same trend as precipitation and stream flow, with the exception of a 1.5 month shift of the start of ascending values (Fig. 7), indicating vertical soil water travel time. G02 (Fig. 6) shows seasonal effects (not shown), calling groundwater as a source for this sampling point into question.

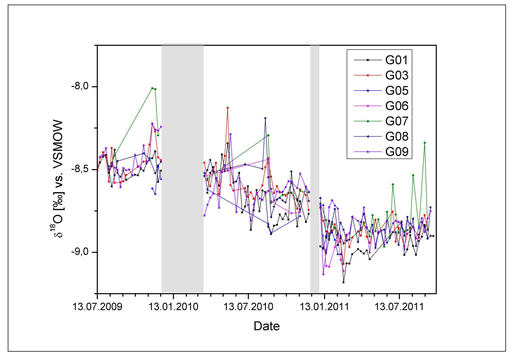

Fig. 7: Groundwater samples show a similar trend as precipitation and stream water, with a 1.5 month shift. Grey shaded areas are sampling gaps.

Groundwater-fed Tributaries (E)

Two more tributaries (sampling points Wu12, 15 and 16) show quasi-constant $\delta^{18}O$ values similar to Wu03 (Fig. 8), indicating groundwater as a source for these tributaries.

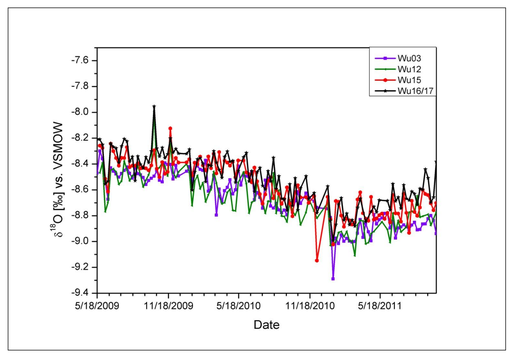

Fig. 8: Tributaries from sampling points Wu12, 15 and 16 show the same quasi-constant behaviour as the groundwater-fed Wu03 (see also Fig. 6 for location of the tributaries).

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